California Energy Commission
CHP/DG Market and Policy Workshop
Sacramento
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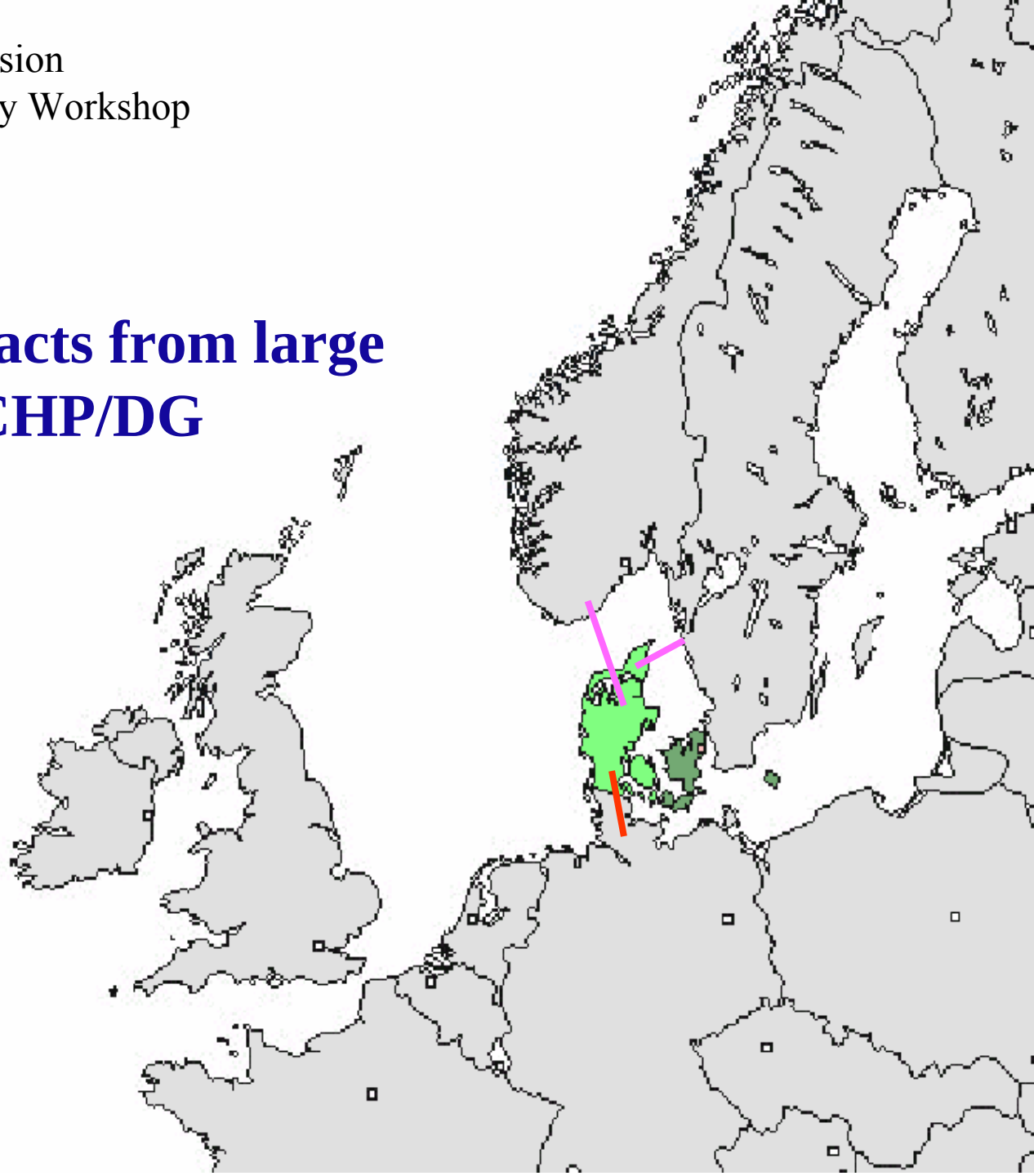
Operational impacts from large penetrations of CHP/DG

Paul-Frederik Bach

Eltra
Independent
System Operator
for the western
part of Denmark



The Story of a Power System Transformed…

…from centralized generation in the mid-eighties

…into distributed generation (DG) by 2000

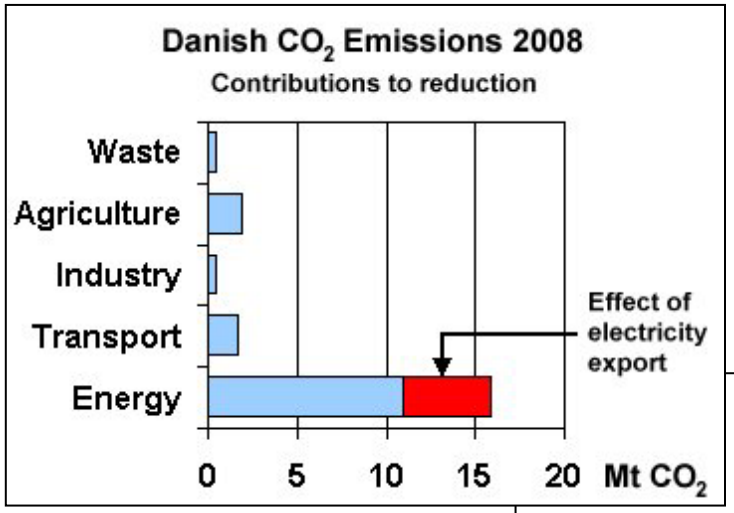
The Headlines

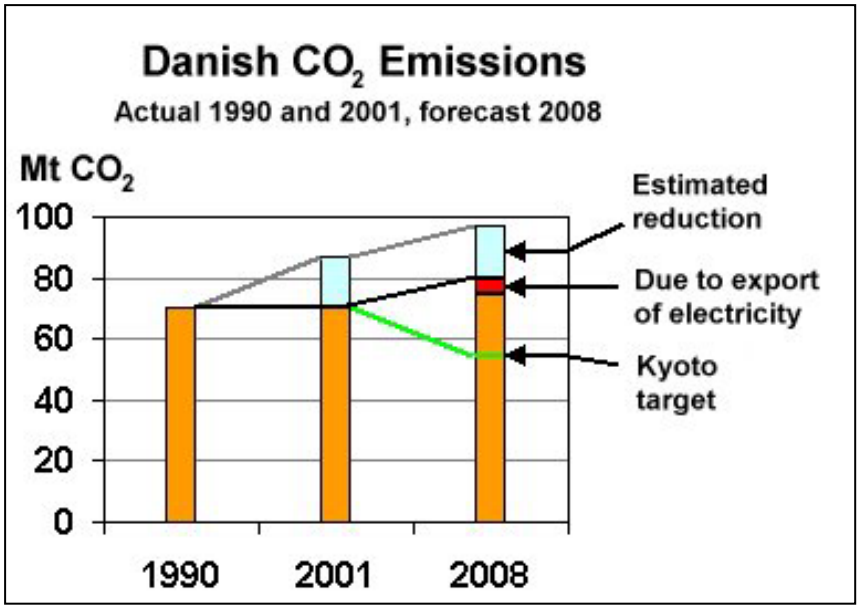
1. Political Background
2. DG Penetration
3. Risk and Rescue
4. Short Term Measures
5. A New System Architecture
6. Towards more DG?

It took Decades to Develop CHP in Demark

- Houses in Denmark need space heating most of the year
- Large scale CHP in Copenhagen since the 1930s
- Power generation elsewhere gradually centralized after ww2
  - Most new power stations were located close to urban areas
  - Large district heating schemes were developed in major cities
- After the energy crisis in 1973
  - A national energy policy 1976
  - Heat supply law 1979 **(ref. 1)**
  - Natural Gas Supply Planning Act 1979 **(ref. 2)**
  - All areas in Denmark assigned for either district heating, natural gas or individual heating schemes
  - Ban on electric heating
  - 60 % share of district heating in 2002, of which 74 % CHP **(ref. 3)**

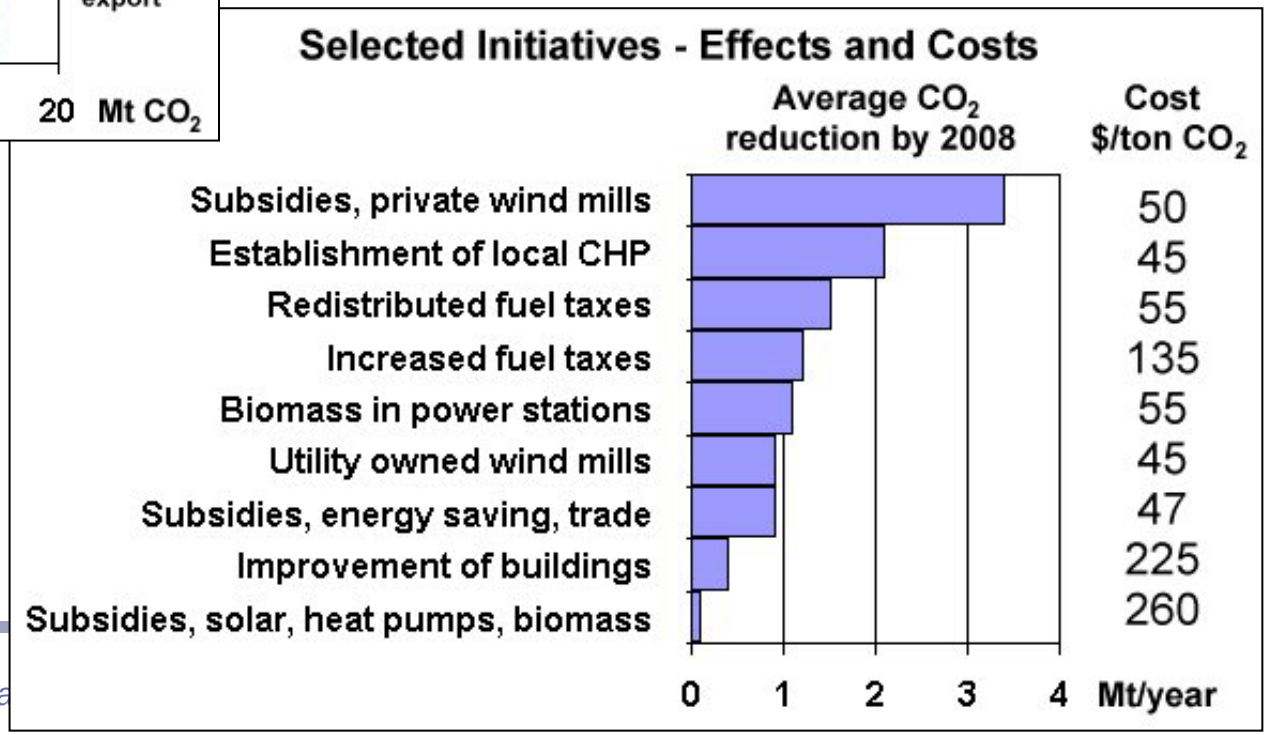
CO2 Emission in Denmark Effects and Costs 1990-2001



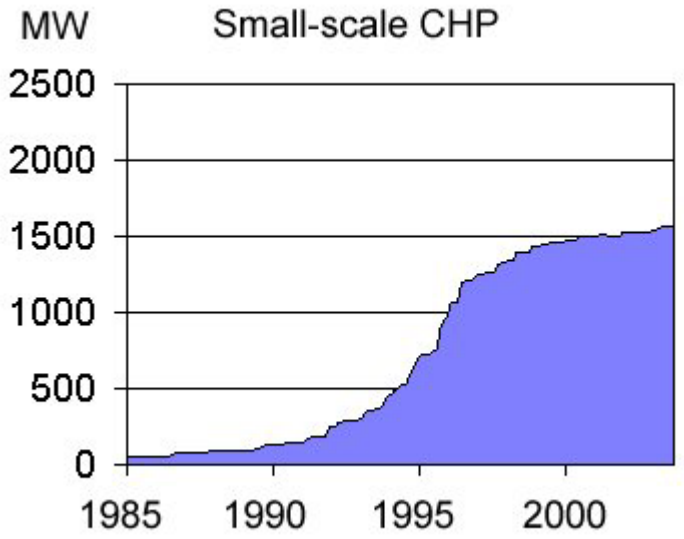


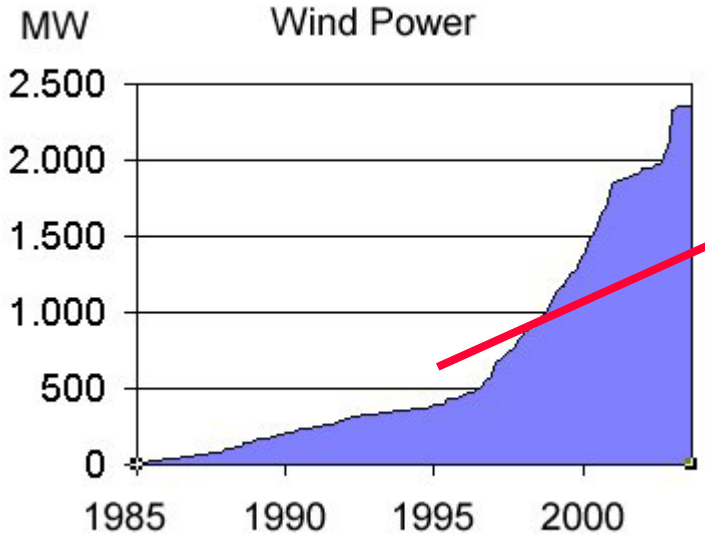
Danish Environmental Protection Agency

April 2005



A Surge of Small-scale CHP and Wind Power



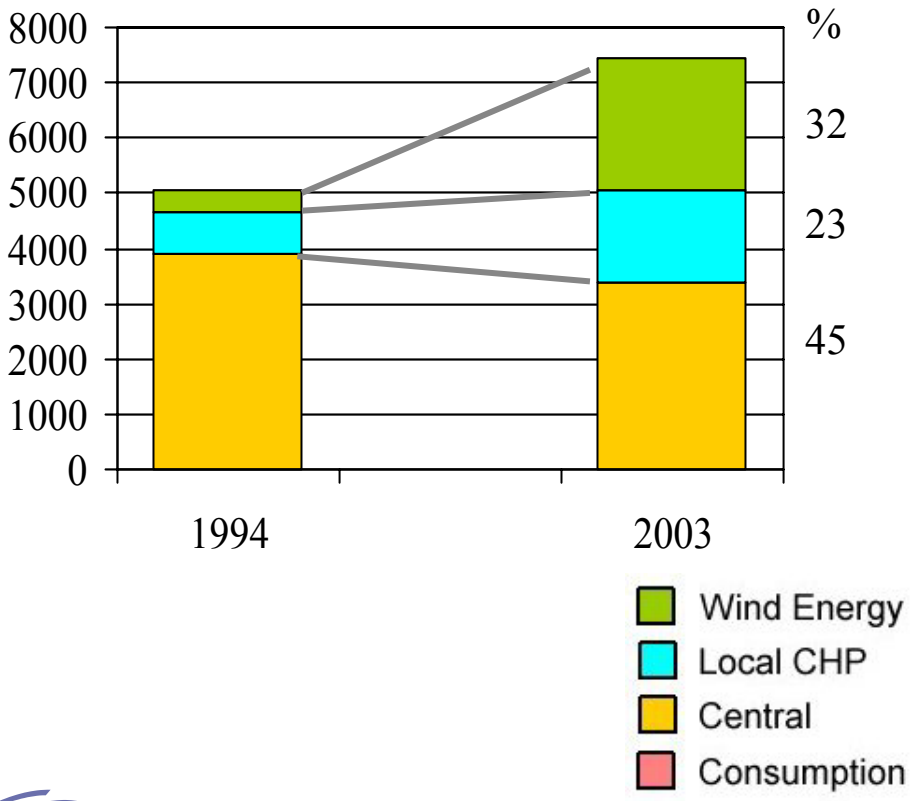


DK West
(2,374 MW ult. 2003)

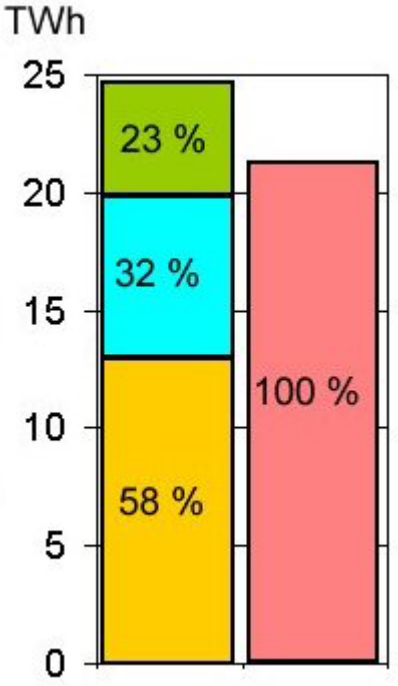
National target
(1,500 MW in 2005, ”Energy 21”, 1996)

DG Exceeding 50 %

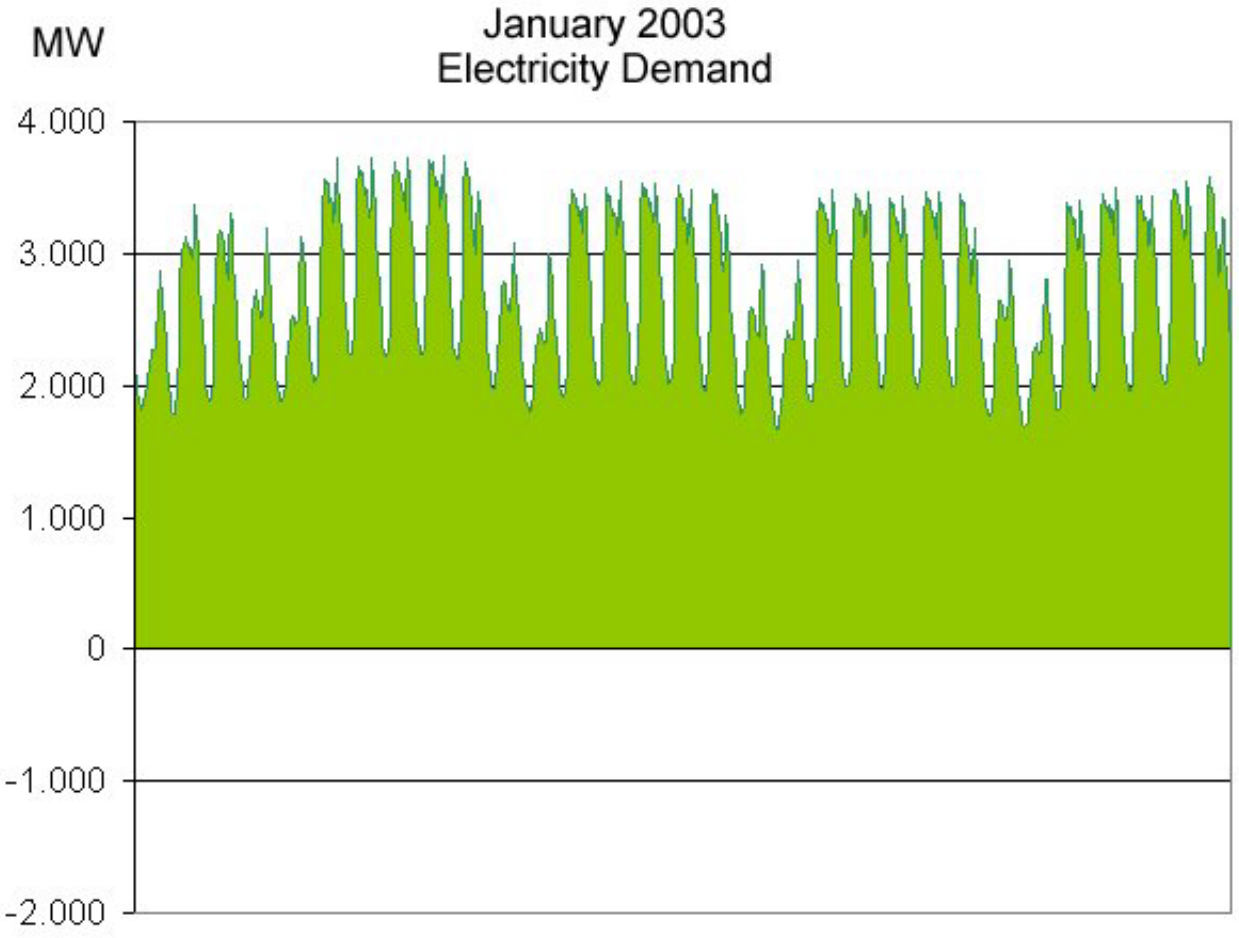
Installed capacity MW



Energy Balance 2004

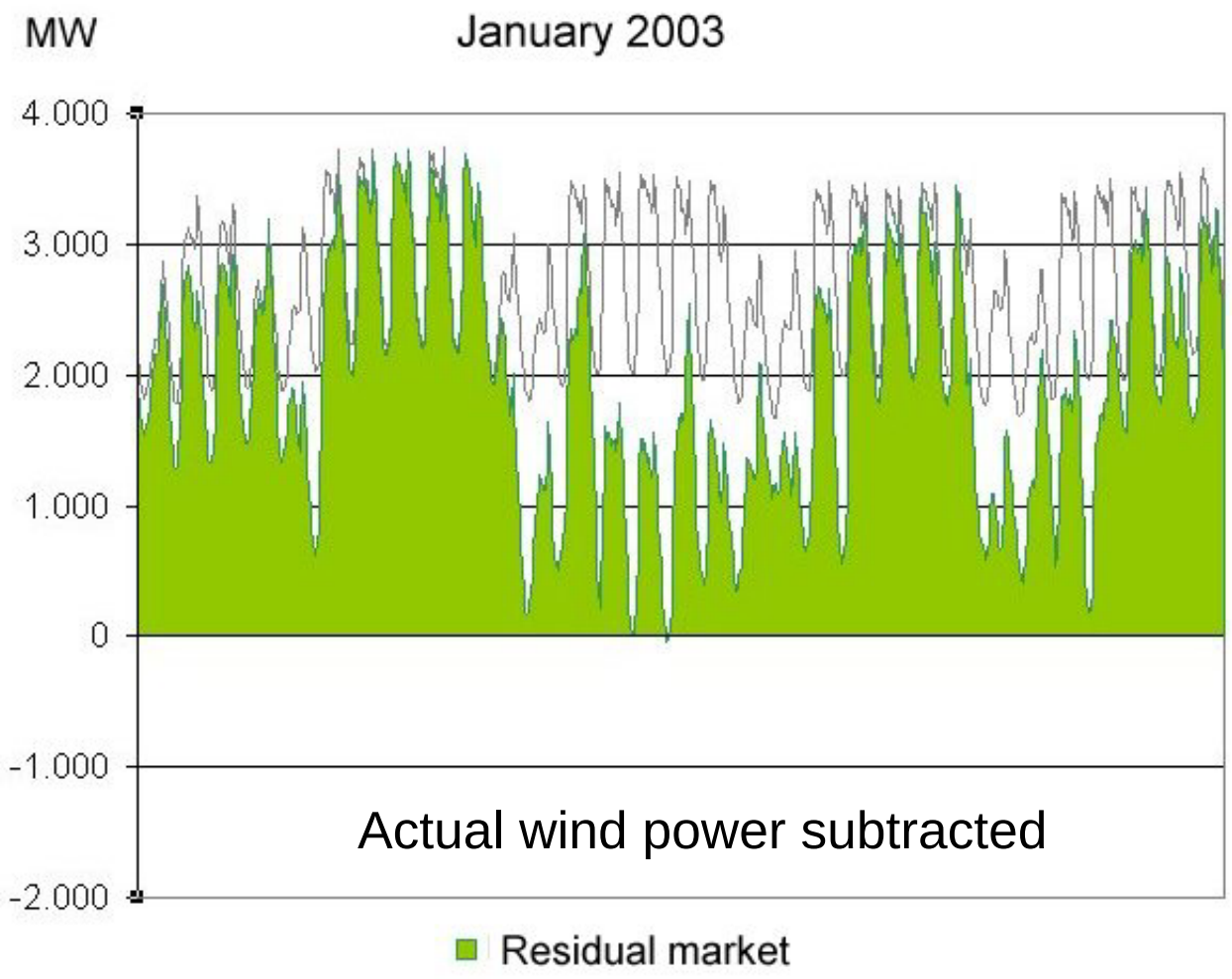


A closer look: January 2003



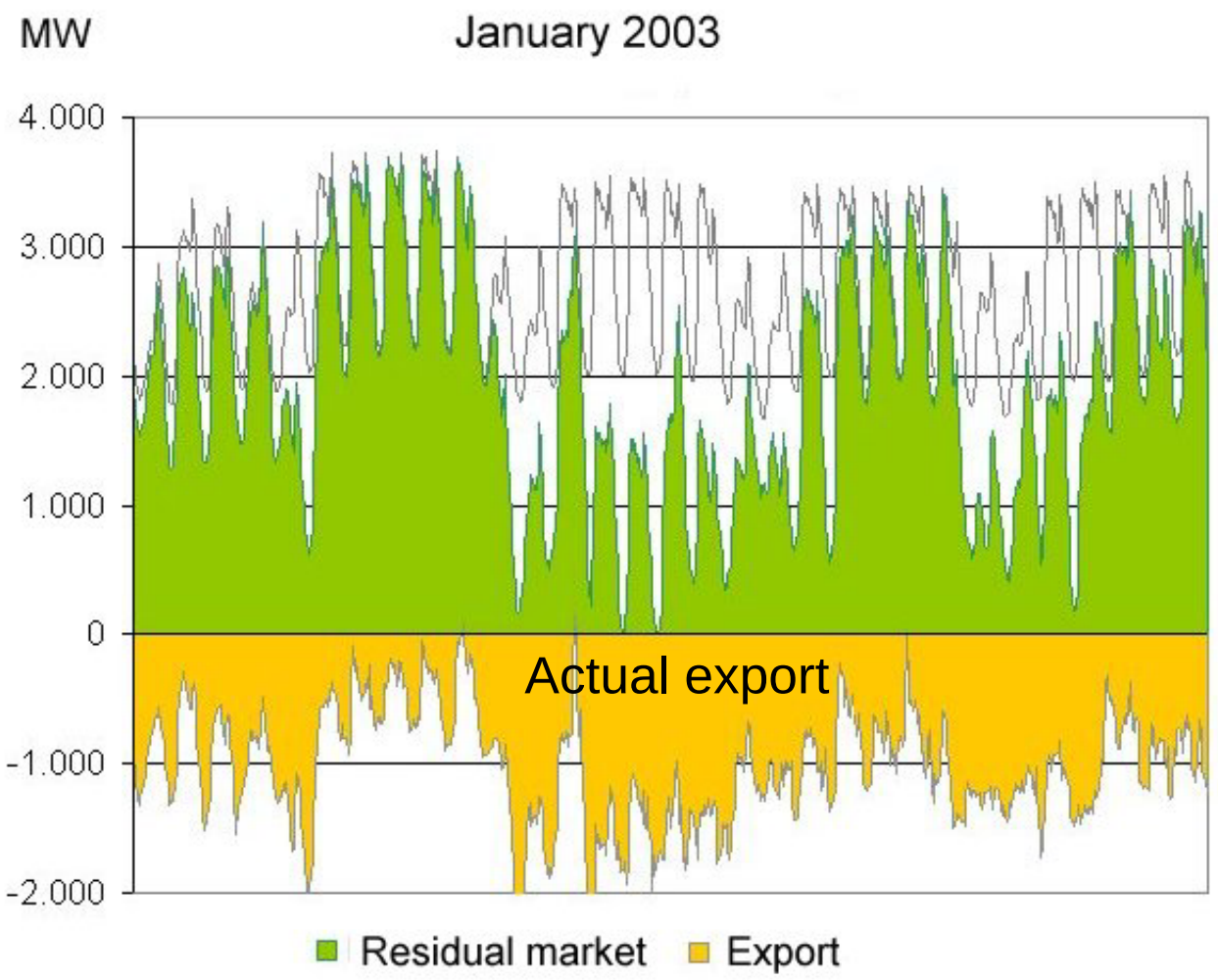
Domestic base load market: about 1,800 MW

The Residual Market



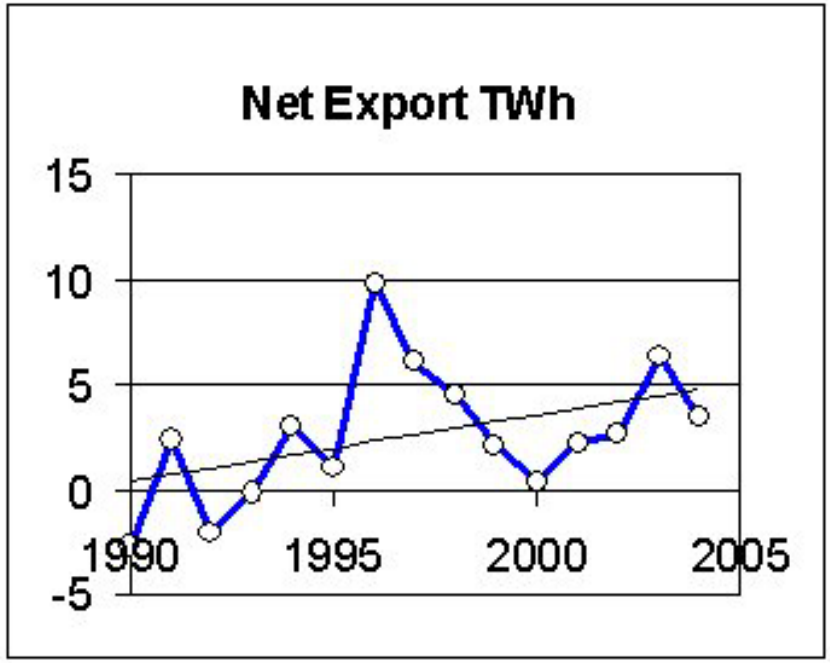
No domestic market for traditional base load units left

Export Caused by Priority CHP



Increasing Surplus of Electricity

- Operation of central units is constrained by heat demand or reserve duties
- Therefore, growth in wind power and local CHP cannot displace production from the central units,
- and export of electricity is growing regardless of electricity demand



Result of DG Penetration

- Market for traditional base load units distorted by wind power
  - **Doubtful if producers will invest in new base load units**
- Overflow of electricity during windy periods
  - Wind power and CHP electricity are competing for a limited electricity demand
  - Priority for CHP units is causing unintended export of electricity
  - There is no credit on the Kyoto account for export of electricity
  - Therefore, **wind power should displace thermal electricity, when electricity demand is scarce**

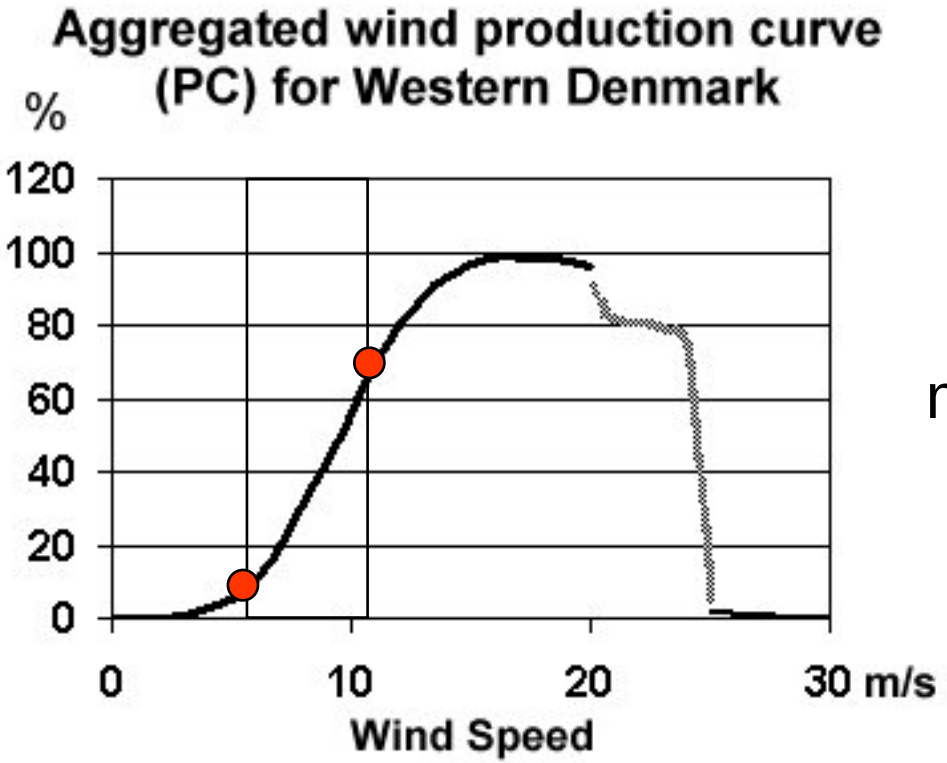
Eltra Merging into a National TSO

- It is a main task for Eltra to maintain normal security of supply
- On January 1, the Danish state took over the ownership of Eltra
- During the spring of 2005 Eltra will merge into **Energinet.dk**, the future national TSO for electricity and gas
- Read more on www.eltra.dk

Inadequate load following capacity

- Supply and demand of electricity must be equal
  - Electricity consumers decide demand profile
  - Wind power is controlled by wind only
  - Local CHP so far controlled by heat demand and time-of-day tariffs
  - Large generators follow market signals, but constrained by heat demand and design as base load units
- The load-following capability of the domestic production system is inadequate

Big Errors in Wind Power Forecasting

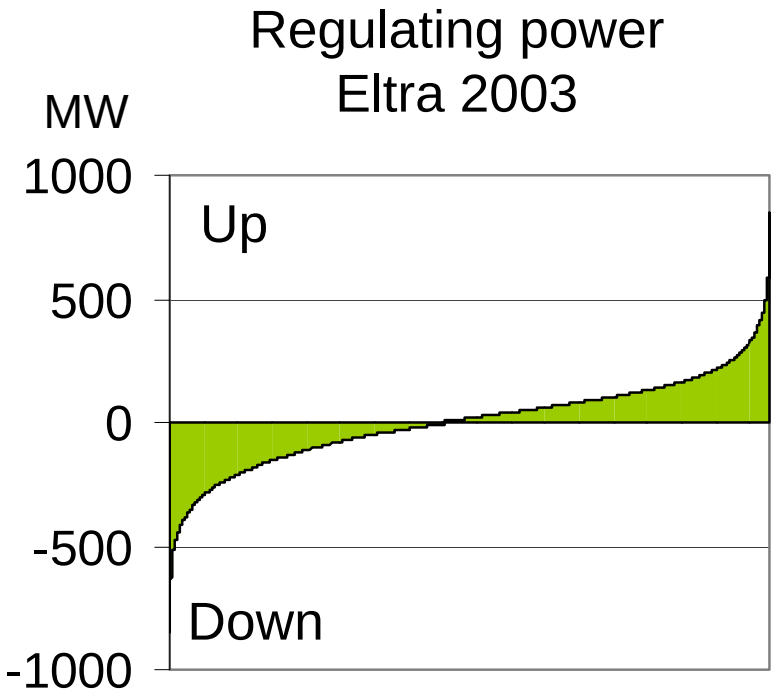


"Fresh breeze" means somewhere between 200 and 1,600 MW

A deviation of just +/– 1 m/s may have an impact of +/– 320 MW (With a 2,374 MW installed base).

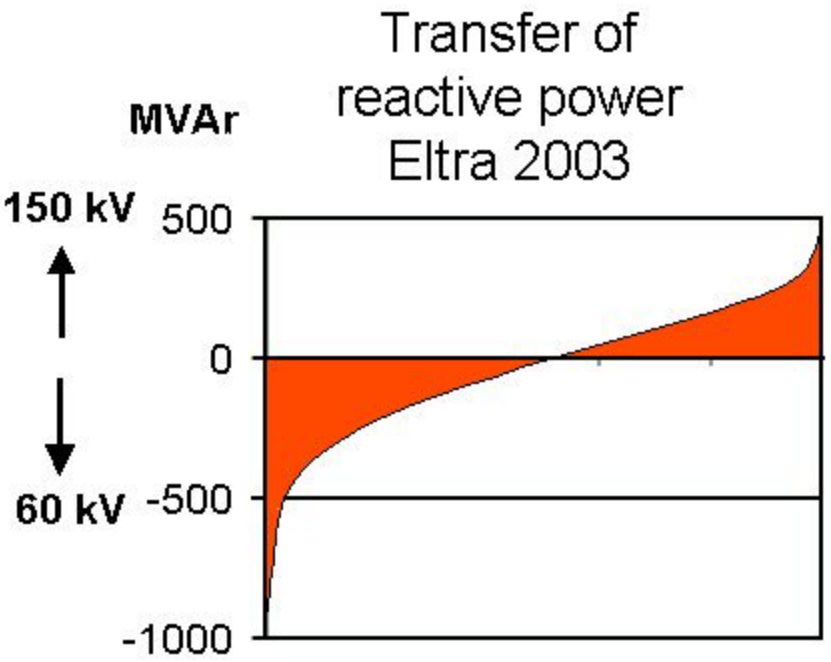
Purchase of Regulating Power

- Errors in wind power forecasting and poor load-following capability cause a high need for regulating power
- Eltra purchases regulating power locally and abroad
- Maintaining system balance between production and consumption has become expensive



Balancing reactive power

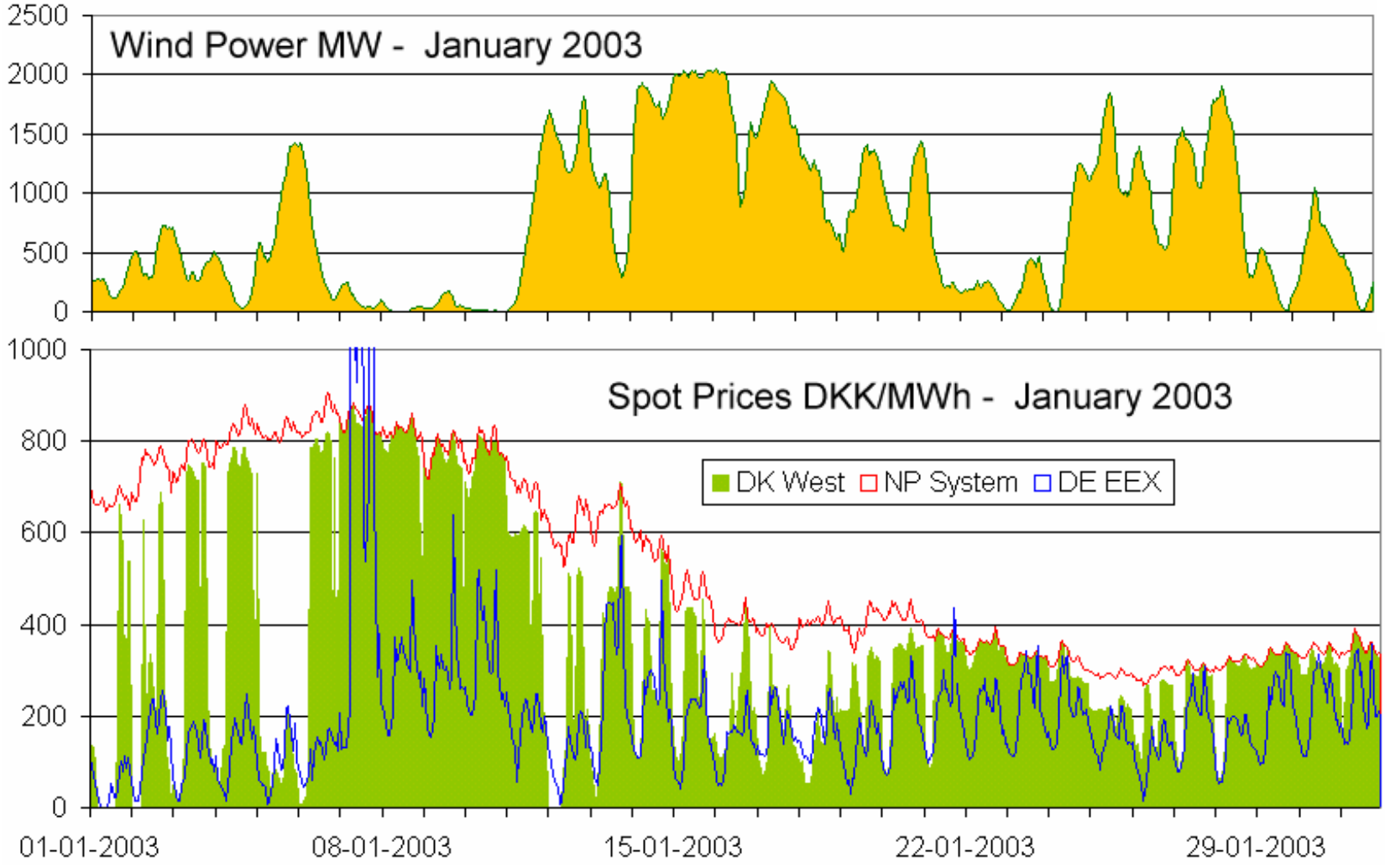
- Transfer of reactive power causes increased losses and expensive compensative measures in the transmission system
- Reasons are time-of-day setting for tan φ on local CHP plants and insufficient compensation of wind power



DG Market Impact

- So far prioritized power have been fed into the system without regard to electricity demand
- For a small area like Denmark West periods without wind power at all will occur
  - Therefore, capacity credit for wind power is very debatable
- Area Price ”DK West” is typically somewhere between the Nord Pool system price and the EEX price
- Wind power fluctuations have a considerable impact on the area price (see a case on next slide)

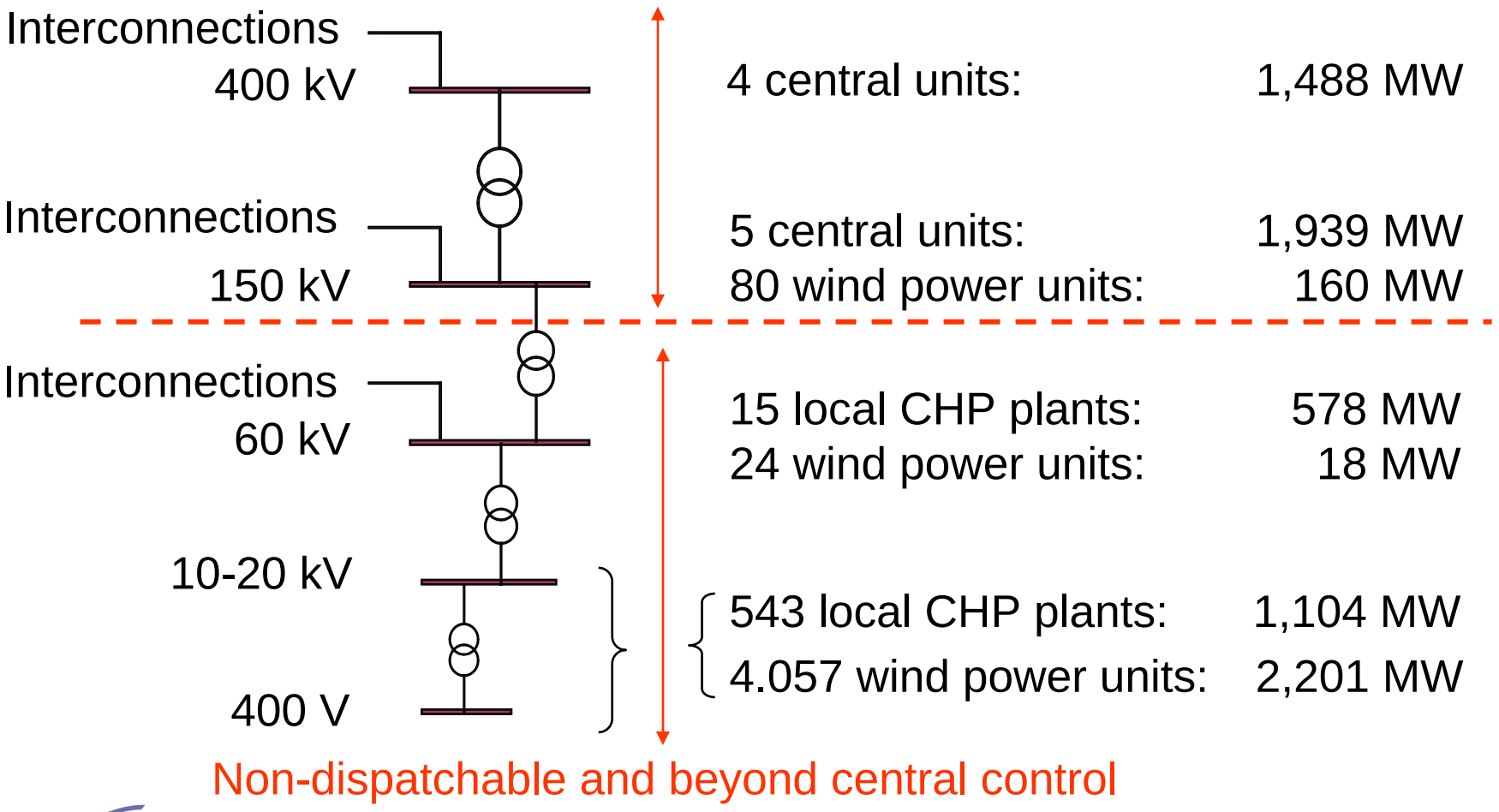
DG Market Impact (case)



Markets players have limited confidence in a volatile market

Distribution of Production Capacity (January 1, 2005)

Range of central control

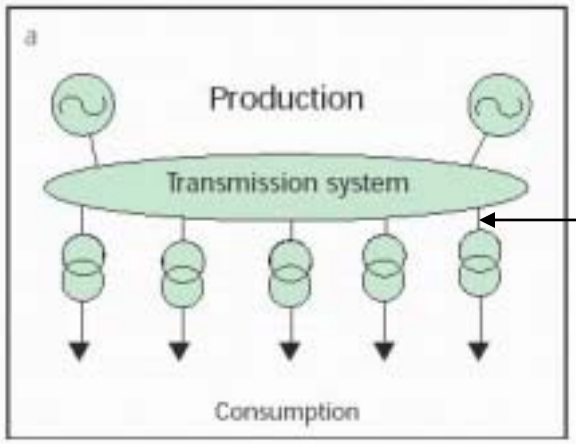


Non-dispatchable and beyond central control

Security Problems Identified

- Local grids cannot maintain normal n-1 security
  - if local generation exceeds local demand and
  - if separation of generation and consumption is insufficient
- Security analyses have become less accurate due to missing information on local generation and unpredictable wind power
- Protection relays trip local generators after distant faults
- Traditional under-frequency load shedding schemes will disconnect both load and generation
- Restoration after fault has become more complicated and more time consuming

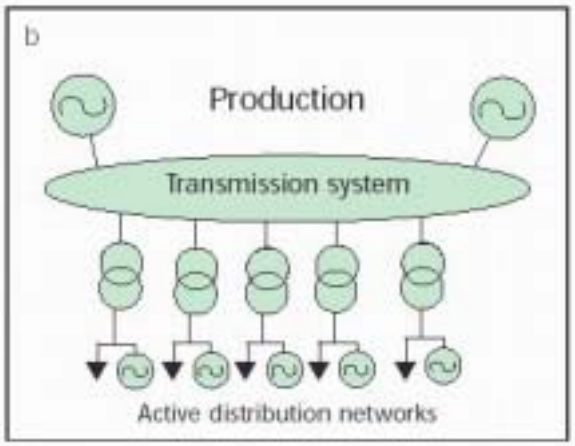
From passive to active local grids



The traditional one-way supply system

Easy prediction and security analyses by **observation at transfer nodes**, because loads are quite uniform

Local networks have become active and unpredictable



Data from local grids
on generation, load and grid configuration are required for accurate system analyses

The Lifelines

Important conditions for safe operation of the Eltra power system so far:

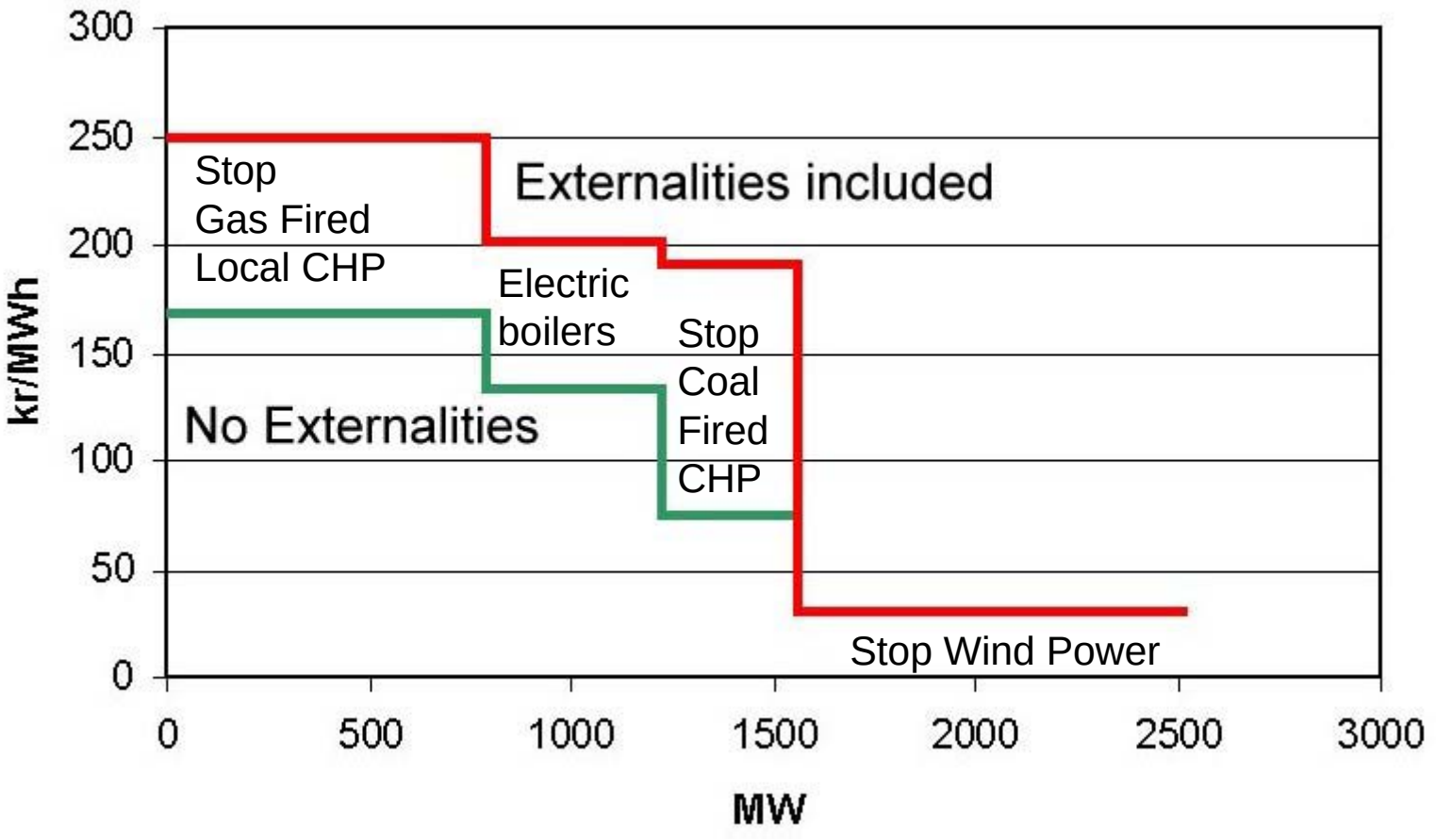
- The Nord Pool spot market
- The real-time market
- Strong interconnections to Norway, Sweden and Germany
- Strong a.c. interconnections to Germany

Without access to purchase of regulating power in neighboring countries wind power would frequently have been curtailed

Summary of problems

- Maintaining balance of active and reactive power has become difficult and expensive
- Lack of confidence in the electricity market among market players due to volatile prices
- System security has deteriorated
  - Increased risk of serious system disturbances
- **However, distributed generation is not the problem…**
  - but the DG penetration was too fast
- The system architecture must be redesigned for DG
  - **Local CHP can contribute to system balance and security**
    - if system control is properly organized

Incremental cost for decreasing production



Data: RES-Report DEA Oct. 2001

Improving Flexibility of Generation

- The 3 production modes for local CHP:
  - heat only
  - electricity only
  - combined heat and power
- Legislation prevented use of this flexibility so far
  - New act allowing market based operation from January 1, 2005
- Pilot project PUDDEL paving the way for a transition:
  - From prioritized operation of local CHP to market based operation
  - Includes 30 units (400 MW) and 6 balance-responsible operators
- CHP-schemes can contribute further by electric water heating
  - This is legal for industrial projects, but not for district heating

Other Short-term Measures

- Introducing price responsive electricity demand
  - End consumers
  - Water heaters and heat pumps for district heating systems
- Local grid companies must actively control their own grids
  - Control of reactive power and voltages
  - Shedding local load or generation during emergencies
  - Restoring local grids after failure including local start after blackout
- Wind power forecasting must be improved
  - Using weather forecasts from more than one Met Office
  - Development and test of the Meltra forecasting tool using the ensemble method on a cluster of computers at Eltra

Our Targets

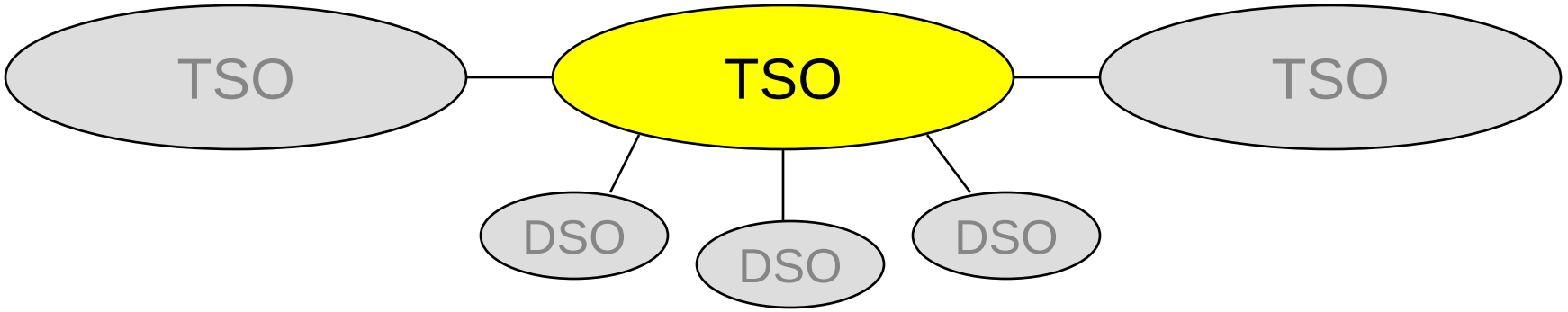
- Sufficient domestic resources for maintaining balance between demand and generation
  - Avoid export if market price cannot cover the marginal production costs
- Improved operator knowledge of actual system condition, both locally and centrally
- Efficient system control, particularly during emergencies
- Effective defensive measures against blackouts
- Black start capabilities using local generators

Towards a New System Architecture

- Ambitious wind power programs are being prepared in other countries
- In Germany a study on measures for integrating 36,000 MW wind generation by 2015 has been published (covering about 16 % of the electricity consumption)
- Denmark must develop domestic reserves and other ancillary services in order to contribute on equal terms to stability and security in the interconnected European power system
  - A number of short-term measures have been identified
  - Elements from EPRI's *Intelligrid* and DOE's *Gridwise* define the long-term measures

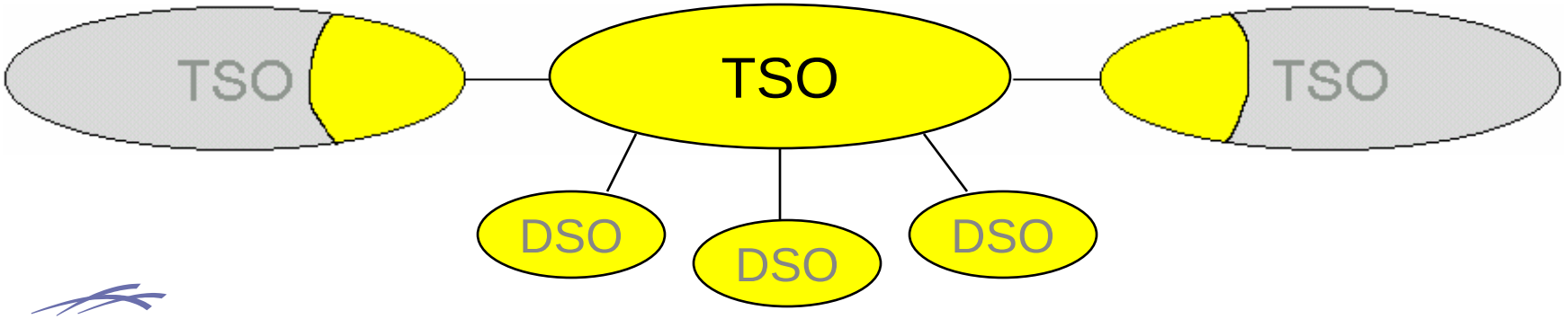
More data needed

for reliable security analyses and for appropriate system control



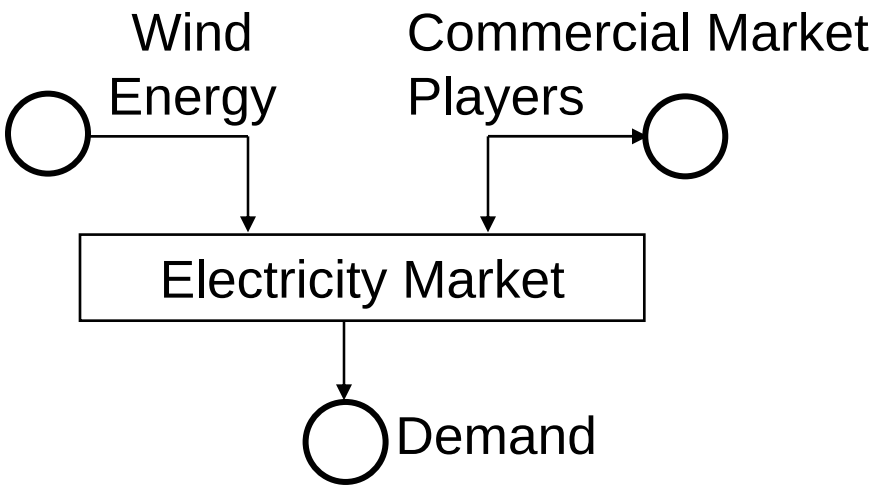
Limited access to data for neighboring TSOs and for local DSOs

Distributed generation and long-distance transfers
require better access to relevant data, both horizontally and vertically



Prospect of more Wind Power?

- Wind energy covering 35 % of Danish electricity demand by 2015 is being discussed
- **Reduced electricity production from local and central CHP schemes must be anticipated**
- Measures to stabilize grid operation without thermal plants must be prepared
- The commercial market players will find good opportunities in the residual market, but they must replace traditional base-load units with more flexible units



- An international trend towards more DG should be supported by efficient coupling of the electricity markets for spot and real time trade.
- **Electricity consumers will face an increased cost of electricity**


eltra

References

1. Danish Energy Authority: HEAT SUPPLY: GOALS AND MEANS OVER THE YEARS - http://www.ens.dk/sw14621.asp
2. Poyal Danish Ministry of Foreig Affairs: ENVIRONMENT AND ENERGY- http://www.um.dk/Publikationer/UM/English/FactsheetDenmark/EnvironmentAndEnergy/index.htm
3. Danish Board of District Heating: STATISTICS - http://www.dbdh.dk/dkmap/statistics.html